EXTENDED REPORT

Combining information obtained from magnetic resonance imaging and conventional radiographs to detect sacroiliitis in patients with recent onset inflammatory back pain

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Objective: To compare the contribution of changes on magnetic resonance imaging (MRI) and conventional radiography (CR) in the sacroiliac joints of patients with recent onset inflammatory back pain (IBP) in making an early diagnosis of spondyloarthritides.
Methods: The study involved 68 patients with IBP (38% male; mean (SD) age, 34.9 (10.3) years) with symptom duration less than two years. Coronal MRI of the sacroiliac joints was scored for inflammation and structural changes, and pelvic radiographs were scored by the modified New York (mNY) grading. Agreement between MRI and CR was analysed by cross tabulation per sacroiliac joint and per patient.
Results: A structural change was detected in 20 sacroiliac joints by MRI and in 37 by CR. Inflammation was detected in 36 sacroiliac joints by MRI, and 22 of these showed radiographic sacroiliitis. Fourteen patients fulfilled the mNY criteria based on CR. Classification according to the modified New York criteria would be justified for eight patients if it was based on MRI for structural changes only, for 14 if it was based on structural changes on CR, for 14 (partly) different patients if it was based on inflammation on MRI only, for 16 if it was based on inflammation and structural changes on MRI, for 19 if it was based on inflammation on CR combined with MRI, and for (the same) 19 if it was based on inflammation and structural damage on CR combined with MRI.
Conclusions: CR can detect structural changes in SI joints with higher sensitivity than MRI. However, inflammation on MRI can be found in a substantial proportion of patients with IBP but normal radiographs. Assessment of structural changes by CR followed by assessment of inflammation on MRI in patients with negative findings gives the highest returns for detecting involvement of the SI joints by imaging in patients with recent onset IBP.

Ankylosing spondylitis is the prototype disease in the group of spondyloarthritides. To classify patients as having ankylosing spondylitis according to the most widely used criteria, the modified New York criteria, radiographic sacroiliitis is obligatory.[1] A spondyloarthropathy classification can also be made without sacroiliitis on radiographs according to the Amor or European Spondylarthropathy Study Group (ESSG) criteria.[2 3] It has been hypothesised that spondyloarthropathy with axial involvement not (yet) fulfilling the modified New York criteria may involve an earlier and less severe part of the spectrum of ankylosing spondylitis.[4]

Making an early diagnosis of spondyloarthropathy with axial involvement is challenging. One of the reasons for this is that sacroiliitis on radiographs is a rather late phenomenon and difficult to interpret reliably.[5] Magnetic resonance imaging (MRI) has been proposed as an imaging method to detect sacroiliitis earlier.[6] MRI can identify both inflammation and structural changes caused by inflammation, while radiographs show only structural changes. MRI may be particularly useful in making a diagnosis of spondyloarthritides in patients presenting with inflammatory back pain (IBP). In the present study we compared the performance of MRI and conventional radiographs (CR) of sacroiliac joints in patients with recent onset IBP with a relatively high level of suspicion of spondyloarthropathy. We compared both imaging modes with respect to structural changes, and we compared inflammation on MRI and structural changes on CR. Comparisons were made at the level of single joints and at the level of patients, by applying the modified New York criteria and substituting CR information by MRI information in the radiographic criterion.

METHODS

Patients

Patients with inflammatory low back pain present for two years at most were eligible for inclusion in the study. IBP was defined according to the Calin criteria, which require four of the five following characteristics to be present: insidious onset; onset before the age of 40 years; persistence for at least three months; association with morning stiffness; and improvement with exercise.[7] Patients could also be included if three of the five criteria were present plus night pain. Preferably, but not obligatorily, patients should have at least one of the following features of spondyloarthritis according to the ESSG criteria: presence of a family member with ankylosing spondylitis; presence or history of psoriasis, inflammatory bowel disease, or uveitis.

The study was approved by the institutional review board and all patients gave their written informed consent.

Abbreviations: ESSG, European Spondylarthropathy Study Group; IBP, inflammatory back pain; STIR, short tau inversion recovery

Table 1 Baseline characteristics of 68 patients with chronic inflammatory low back pain

Characteristic	All patients (n = 68)
Sex (% male)	38
Age (years) (mean (SD))	34.9 (10.3)
Symptom duration (months) (median (IQR))	18.0 (12.0 to 24.0)
Criteria for inflammatory low back pain:	
3 criteria present	56%
4 criteria present	41%
5 criteria present	3%
Night pain present	96%*
HLA-B27 present	46%
History of IBD present	15%
History of uveitis present	15%
History of psoriasis present	24%
Family history of AS present	37%
Fulfilling ESSG criteria	84%
Fulfilling Amor criteria	71%
Fulfilling both ESSG and Amor criteria	63%

*45 of the 47 patients who were asked about night pain.
AS, ankylosing spondylitis; ESSG, European Spondylarthropathy Study Group; IBD, inflammatory bowel disease; IQR, interquartile range.

MRI

An MRI examination of the sacroiliac joints was undertaken using a 1.5 T Philips Gyro Scan ACS-NT. Patients were scanned in the supine position using a Synergy-spine coil as the surface coil. We chose a coronal oblique scan plane parallel to the length of the sacrum. Two slabs were employed—one transverse, positioned cranially to the region of interest to diminish flow artefacts, and one frontally through the bowel and anterior abdominal wall, to diminish motion artefacts from breathing and bowel movements. The following sequences were used: T1 weighted spin echo (SE), short tau inversion recovery (STIR), T2 weighted fast SE with fat saturation and T1 weighted SE with fat suppression after the intravenous administration of contrast medium (gadolinium diethylenetriaminepentate, 0.1 mmol/kg body weight).

Inflammation was scored for each sacroiliac joint in the joint space, subchondral bone, bone marrow, ligaments, and joint capsule. Inflammation was defined as a low signal intensity on T1, with enhancement after gadolinium administration, and/or high signal intensity on STIR, and/or T2 fast SE. Inflammation in ligaments was defined as areas of low signal intensity running through high signal intensity tissue on T1, which reflects interosseous ligaments crossing juxtaarticular fatty tissue. Structural changes (erosions, sclerosis, ankylosis) were scored in joint space, subchondral bone, and bone marrow. Each sacroiliac joint was labelled as showing inflammation or structural changes if these respective features were present in at least one of the areas investigated. Each set of MRIs was scored independently by two observers, who were blind to the patient identity and to the clinical, laboratory, and radiological data. All joints that showed a discrepancy between the readers for inflammation or structural damage, or both, were offered to a third reader. In all, 21 discrepant joints were scored for the assessment of structural change. The final score attributed to the joint was based on a two out of three majority score. A similar process was followed for discrepancies in inflammation. For this purpose 25 discrepant joints were offered to a third reader.

Conventional radiography

Anteroposterior conventional pelvic radiographs were scored independently by two observers—who were not involved in the MRI reading—without knowledge of clinical information, according to the modified New York criteria (from zero (normal) to 4 (complete ankylosis)).[1] In case of discrepancy between the readers, a third reader (who was not involved in the MRI scoring) scored the sacroiliac joint. In all, 42 discrepant sacroiliac joints were offered to the third reader. A final score for each sacroiliac joint was assigned on the basis of the majority score of the three observers.

Analysis

For conventional radiography, the scores were dichotomised. A sacroiliac joint with a majority score of 0 or 1 was considered normal; a joint with a majority score of 2 or more was considered to have radiographic sacroiliitis. For fulfilment of the modified New York criteria we also substituted CR information by MRI information in five different ways so that patients could fulfil the modified New York criteria as follows:

(1) according to the original method based on radiographs;
(2) based on structural changes present on MRI in both sacroiliac joints;
(3) based on inflammation present on MRI in both sacroiliac joints;
(4) based on inflammation and/or structural changes present on MRI in both sacroiliac joints;
(5) based on structural changes on CR combined with inflammation with or without structural changes on MRI in both sacroiliac joints.

If based on radiographs, patients with bilateral grade 2 sacroiliitis, or at least unilateral grade 3 sacroiliitis, were classified as fulfilling the modified New York criteria. If based on MRI, the mere presence of structural damage for definition 2, the mere presence of inflammation for definition 3, or one of both for definition 4 were considered sufficient, and severity or extent of the lesions was ignored. For definition 5 the grading for CR and the presence of inflammation on MRI were combined.

Agreement between structural changes on MRI and sacroiliitis on CR as well as agreement between inflammation on MRI and sacroiliitis on CR was analysed by cross tabulation. This was done both per sacroiliac joint and per classification according to the modified New York criteria. Specificity, sensitivity, and positive and negative predictive values were calculated with conventional radiography as the gold standard.

RESULTS

Patients

The characteristics of the 68 patients included in the study are presented in table 1. Fifteen patients (22%) did not have any of the additional spondyloarthropathy features. Of these 15 patients, seven were HLA B27 positive. Fifty seven patients

Table 2 Comparison of structural changes observed on MRI with structural changes on conventional radiographs based on the modified New York criteria

	Radiographs of SI joint*		
Structural changes on MRI	Abnormal	Normal	Total
(a) *Single sacroiliac joint analysis*			
Present	18	2	20
Absent	19	97	116
Total	37	99	136
(b) *Per patient analysis*			
Present in both SI joints	8	0	8
Present in one SI joint	2	2	4
Absent	4	52	56
Total	14	54	68

*Patients fulfilled the modified New York criteria on MRI if structural changes were present and on conventional radiography if there were bilateral changes of at least grade 2 or unilateral of at least grade 3.
MRI, magnetic resonance imaging; SI, sacroiliac.

fulfilled the ESSG criteria, 48 fulfilled the Amor criteria, and 43 fulfilled both sets of criteria.

Adjudication for structural and inflammatory changes on MRI

After the readings by the two observers, there was agreement on the presence of structural change in 17 joints, and on the absence of structural change in 98 joints. Adjudication of the 21 joints where there was a discrepancy in the readings led to a decision that a further three joints should be classed as positive for structural change (all with erosions). One of these was scored positive in a patient in whom the other sacroiliac joint had also been scored positive in the original read; the other two joints were in a single patient, who had been scored as having structural change in both joints by one of the two readers in the original read.

There was agreement on the presence of inflammation in 32 joints, and on the absence of inflammation in 79 joints after the reading by the two observers. Adjudication of 25 joints with a discrepancy for inflammatory changes led to the assignment of inflammation in four additional joints. These joints were all in patients in which both readers already considered unilateral inflammatory changes to be present. Adjudication did not yield additional patients with inflammation.

Adjudication for changes on CR

There was agreement on the presence of sacroiliitis in 29 joints, and on the absence of sacroiliitis in 65 joints. The adjudication of the 42 discrepant joints led to the assignment of eight further joints to the positive group. In four patients adjudication resulted in fulfilment of the modified New York criteria, as these patients showed already grade 2 abnormalities in the contralateral sacroiliac joint.

Abnormalities on MRI

In all, 20 sacroiliac joints in 12 patients showed structural changes on MRI (table 2). Thirty six joints in 22 patients showed signs of inflammation on MRI (table 3). Twelve of these 22 patients also had structural changes on MRI. None of the patients had structural changes on MRI without inflammation.

Abnormalities on conventional radiography

On conventional radiography 37 sacroiliac joints in 23 patients showed radiographic sacroiliitis (28 grade 2, nine grade 3). Fourteen patients fulfilled the radiographic criterion of the modified New York criteria for ankylosing spondylitis:

Table 3 Comparison of inflammation observed on MRI with structural changes on conventional radiographs based on the modified New York criteria

Inflammation on MRI	Radiographs of SI joint*		
	Sacroiliitis	Normal	Total
(a) *Per joint analysis*			
Present	22	14	36
Absent	15	85	100
Total	37	99	136
(b) *Per patient analysis*			
present in both SI joints	9	5	14
present in one SI joint	3	5	8
Absent	2	44	46
Total	14	54	68

*Radiographs of the sacroiliac joints were scored according to the modified New York criteria, which were met if bilateral grade 2 or unilateral grade 3 or 4 sacroiliitis was scored.
MRI, magnetic resonance imaging; SI, sacroiliac.

Table 4 Comparison of inflammation or structural changes observed on MRI with structural changes on the conventional radiography based on the modified New York criteria

Inflammation and/or structural changes on MRI	Radiographs of SI joint*		
	Sacroiliitis	Normal	Total
(a) *Per joint analysis*			
Present	24	14	38
Absent	13	85	98
Total	37	99	136
(b) *Per patient analysis*			
Present in both SI joints	11	5	16
Present in one SI joint	1	5	6
Absent	2	44	46
Total	14	54	68

*Radiographs of the sacroiliac joints were scored according to the modified New York criteria, which were met if bilateral grade 2 or unilateral grade 3 or 4 sacroiliitis was scored.
MRI, magnetic resonance imaging; SI, sacroiliac.

nine patients because of bilateral grade 2 sacroiliitis; four because of bilateral grade 3 sacroiliitis, and the remaining patient because of grade 2 and grade 3 sacroiliitis combined. The remaining nine patients had unilateral grade 2 sacroiliitis.

MRI findings compared with radiographic findings

A comparison between structural changes on MRI and CR is presented in table 2. In all, 12 patients had structural changes on MRI: eight in both joints and four in one joint. Structural changes on MRI were detected in 20 joints, compared with 37 with radiographic sacroiliitis (54%). In two joints that were considered normal on CR, structural changes were scored on MRI. If radiographic sacroiliitis graded according to the modified New York criteria is considered the gold standard, the sensitivity of detecting chronic changes by MRI per sacroiliac joint is 49% (18/37) and the specificity 98% (97/99). Corresponding positive and negative predictive values were 90% and 84%, respectively.

Only eight of the 14 patients (57%) fulfilling the modified New York criteria for ankylosing spondylitis would fulfil the radiographic criterion if this was based on the presence of structural changes on MRI (table 2 (b)), but nine of these 14 patients had signs of inflammation on MRI in both joints and three in one joint (table 3). The two remaining patients showed only structural changes on MRI in one joint.

In 22 of the 37 joints with radiographic sacroiliitis (59%), inflammation was observed on MRI (table 3 (a)). Of the nine patients with unilateral radiographic sacroiliitis, only one had signs of inflammation on MRI (in both sacroiliac joints). Of the 36 joints with inflammation on MRI (17 left, 19 right), radiographic sacroiliitis was detected in 22 (61%; 11 left, 11 right).

If we consider either inflammation *or* structural changes on MRI as positive findings and compare this with radiographic abnormalities, there is only a small gain compared with the information provided by inflammation alone (table 4). Abnormalities could be identified in two additional joints with MRI, and this appeared to be concordant with the findings on CR. This resulted in two more patients fulfilling the modified New York criteria. Based on the combined information about either inflammation or structural changes on MRI, 11 of the 14 patients (79%) can be identified who fulfilled the modified New York criteria according to CR, and another five patients showing abnormalities on MRI which were not identified on CR. Based on the MRI findings, 16 patients would fulfil the modified New York criteria. If we

combine the information obtained by CR with that obtained by MRI, 19 patients would fulfil the modified New York criteria. In addition there were five patients showing abnormalities on MRI in a single joint in patients not fulfilling the modified New York criteria on CR. CR in combination with inflammation on MRI, or CR in combination with inflammation and structural changes on MRI is equally informative.

Summarising the above information, classification according to the modified New York criteria would be justified for eight patients if it was based on MRI for structural changes only, for 14 patients if it was based on structural changes on CR, for 14 (partly) different patients if it was based on inflammation on MRI only, for 16 patients if it was based on inflammation and structural changes on MRI, for 19 if it was based on inflammation on CR combined with MRI, and for (the same) 19 if it was based on inflammation and structural damage on CR combined with MRI. All patients defined as fulfilling the radiographic modified New York criteria according to the various definitions fulfilled both the ESSG and the Amor criteria except for one patient with bilateral inflammation on MRI, but without structural changes on MRI or CR, who did not fulfil any of the spondyloarthropathy criteria. This patient, who presented with arthritis and was HLA-B27 positive, would fulfil the ESSG criteria and the Amor criteria if inflammation on MRI could be substituted for structural changes on CR with a similar weight. In the six patients with structural changes on CR but not on MRI, features other than radiographic ones ensured that they fulfilled the ESSG and Amor criteria.

DISCUSSION

A comparison of abnormalities of the sacroiliac joints found on MRI and conventional radiography in patients with recent onset IBP yielded important information. First, radiographs were more sensitive than MRI in detecting structural changes. Second, the majority of the joints showing structural changes on MRI or CR also showed inflammation on MRI, as did almost all joints with sacroiliitis on CR. Third, a substantial number of patients showed inflammation on MRI, but without signs of structural change on either MRI of CR. Combining this information led to several conclusions.

First, the data add to the hypothesis that inflammation is the first event, and structural change is a subsequent feature. Depending on the lag time between inflammation and structural changes, a diagnosis of sacroiliitis could be made significantly earlier by using MRI changes of inflammation as an early sign of disease. The causal link between MRI inflammation and radiographic sacroiliitis needs to be proven in a longitudinal analysis, which will be possible with this cohort once follow up images have been made.

A second and rather unexpected conclusion is that CR was the preferred method for assessing structural changes in the sacroiliac joints. We postulated CR as the gold standard for assessing structural change, though this is debatable because CR may either overestimate or underestimate structural change. In case of underestimation by CR, MRI performs worse than we showed in this study. Overestimation of structural changes cannot be ruled out, but is considered unlikely as 12 of the 14 patients fulfilling the modified New York criteria showed either inflammation or structural changes in one or both sacroiliac joints on MRI (MRI confirming CR), and all these patients fulfilled the ESSG and the Amor criteria for spondyloarthritides. We selected conventional radiography as the comparator as this is the most widely used method in clinical practice to make a diagnosis of sacroiliitis. It is known that computed tomography (CT) is a more sensitive method for detecting structural changes, but if that were true in our cohort, the lower sensitivity of MRI would be even more obvious. Combining information on inflammation and structural changes from MRI seems the most logical way of using the information in clinical practice, though by doing so it was still only possible to classify as sacroiliitis 11 of the 14 patients who fulfilled the modified New York criteria on conventional radiography. If we were to use information from MRI only (both inflammation and structural changes), another five patients would be classified according to the modified New York criteria who did not fulfil the criteria on conventional radiography. Combining information on structural changes on conventional radiography with the information of inflammation on MRI classifies the largest number of patients: 14 based on structural changes on CR and five additional patients based on inflammation on MRI. Note that we used abnormalities in both sacroiliac joints on MRI as a requirement for substituting the modified New York criteria. Another five patients would have been classified if unilateral MRI abnormalities had been sufficient. However, in view of a report that the positive predictive value of inflammation in a single sacroiliac joint was disappointingly low (60%) as an indicator of structural change on radiography three years later,[8] we considered unilateral MRI inflammation to be insufficient. In our view the following is the most appropriate way of using imaging methods in patients with early IBP: first, conventional radiography of the pelvis; second, MRI for the assessment of inflammation only in patients who do not fulfil the modified New York criteria. MRI for chronic changes does not seem to add much information to what is already provided by conventional radiography. By following this procedure we combine the strengths of the two imaging methods.

It is well known that assessment of sacroiliitis on conventional radiography has high interobserver variation.[5] We therefore decided to use a two out of three majority judgement. Assessment was first done by two experienced readers. In case of discrepancy, the joints were offered to a third independent reader. Two trained observers did the assessment of the sacroiliac joints on MRI. Overall, there was good agreement on the presence on inflammation and structural changes.[9] A similar process was followed in case of discrepancy between the two readers as described for conventional radiography. Thus differences in scoring methodology or handling of data could not influence the likelihood of positive findings. Readers were also not influenced by prior knowledge: the entire team reading the conventional radiographs was different from the team reading MRI.

Further validation of our results can be derived from follow up of the patients, which is under way. Follow up of the patients will be especially interesting for the 10 who showed inflammation on MRI (five in both joints, five in one) but without structural changes as yet on conventional radiography. The data we presented are valid for patients with recent onset IBP with a high suspicion of spondyloarthropathy as seen by a rheumatologist. Whether the results are also generalisable to patients with a lower likelihood of spondyloarthritis is not known.

Conclusions

Conventional radiography can detect structural changes in the sacroiliac joints with greater sensitivity than MRI. However, inflammation on MRI can be found in a substantial proportion of patients with IBP but with hitherto normal radiographs. Applying only MRI for the assessment of both structural changes and inflammation would underestimate sacroiliitis. Assessment of structural changes on conventional radiography followed by assessment of inflammation on MRI in patients with negative findings yields the highest

probability of detecting involvement of the sacroiliac joints in patients with recent onset IBP.

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